

Surveying the Construction of Super Module 2

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Abstract

The survey of the far detector construction data for SM2 is presented. This data includes information on the pitch, warping and drift of the steel planes. The data for SM1 construction is presented in NuMI-NOTE-GEN-866.

Introduction

The survey for construction of SM2 was carried out with the experience gained from the surveying of SM1 (NuMI-NOTE-GEN-866). However, there are some differences between the two super modules that were important to understand for survey. First, the simple difference that there is a gap between plane 248 and plane 249. The distance of this gap is measured to be 110.8 cm (Jeff Nelson-Private Communication), the gap can also be estimated from the survey (see page 4). This means that the plots involving the z coordinate will have a large offset. The second more important difference is that the laser transmitters had to be moved off the rails as the detector grew. This affected the last 139 planes (See Image 1). Data from these planes should be taken with additional caution. Thirdly, as the detector grew, the geometry did not allow for all the axial bolt points to be measured. This meant that Axial Bolts 1 and 8 had to be estimated off the positions of Axial Bolt 4 and 5. This affected the last 68 planes of data.

Coordinates and Conventions

The coordinate system that was used has already been documented (NuMI-NOTE-GEN-784). In this system +x is west, +y is up and +z is perpendicular to the planes in the approximate direction of the beam. Due to the location of the Vulcan transmitters and the plane being surveyed the measurements are most reliable in x and y and least in z. The coordinate system NuMI-NOTE-GEN-868 presents is based off FNAL survey data collected in December 2001, this coordinate system was used for SM2 survey. The number system of the Axial Bolts and Collar holes is the same. Both were numbered 1-8 increasing in the clockwise direction, with 1 closest to 1 o'clock all when facing south.

Re-calibration

The Vulcan system was calibrated and then transformed to the coordinate system presented in NuMI-NOTE-GEN-868. From time to time the Vulcan needed to be recalibrated. This was done as infrequently as possible as recalibration introduces offsets in the calibrated coordinate system. This has been corrected in part in some of the data (see Collar Data). However, since the purpose of the construction data was to give feedback over the detector as it was built and not over the entire detector when the SM was finished, these corrections are only needed to see overall trends. Generally, the

Vulcan would not be re-calibrated until the detector became too close to the two laser transmitters.

Uncertainties and Errors

The uncertainty in measurements has already been dealt with by several NuMI NOTES (see table below). Since the module points are similar in position (outer edge) to the Axial bolts, Survey lugs and to a lesser extent the ears, a similar error for these points should be expected. The collar is right in the middle of the plane and should (in theory) do better than the other data sets. The error estimated for results presented in this note refer to the statistical error only.

Comparison of different estimates of error uncertainty

Error Estimate	Technique for estimate	Coordinate Of error	Reference
2.4-4.1 mm	Comparison with Laser Tracker	X-Y Plane	NuMI-NOTE-GEN-868
3-4 mm	Comparison with Module Length	X-Y Plane	NuMI-NOTE-GEN-828
5.5 mm	Comparison of Axial Bolts	Z Direction	NuMI-NOTE-GEN- 866

Axial Bolt Data

The axial bolt measurements were used for a variety of tests. The average position was used to determine the pitch of the detector in the z-axis. The rods of axial bolts were also tested to verify that all eight rods were growing in z at the same rate. The mean rod position was also compared with the mean collar position to verify the center of detector was growing at the same rate as the edge of the detector. The data on Axial Bolts 480-482 had some clear (unphysical) problems and is not included.

Results:

Plot 1 shows the pitch of the detector in z. The slope is 59.46 mm/plane. This is slightly different then the SM1 measured value of 59.49 mm/plane. Plot 2 shows the variation of the 8 axial bolts when compared with the average of the 8 axial bolts. The few outlying points are due to surveyor/Vulcan error. Besides the few outlying points there is an obvious correlation in some of the points. This is probably an artifact caused by the difficulties involving the last 68 planes mentioned earlier.

Collar Data

The collar measurements are unique in this data set as they are sensitive to movements of the center of the plane. All the other measurements are sensitive to movements at the outer fringe of the plane. Another reason the collar is surveyed is to verify that the tube, which holds the magnet and the magnets cooling system, will fit in the bore (it did).

Results: Plot 3, Plot 4 and Plot 5 show the collar position in x, y and z versus plane respectively. The slope of the pitch in plot 5 is 59.43 mm/plane, which differs from the axial bolt pitch by 0.03 mm/plane and differs from the measured value of 59.49 mm/plane for SM1. Plot 3 and Plot 4 show the movement of the collar in x-y space. Plot 3 and Plot 4 have no correction for re-calibration. An attempt to correct for re-calibration has been made in Plot 6 and 7. The correction for x and y were done differently. The x correction is similar to what was done for SM1 (NuMI-NOTE-GEN-868), the data point before and after the re-calibration are required to agree. The y correction is more complex than just a simple set of offsets. The y correction was done as the detector was put up. However, it is maybe best just to take all data after ~ plane 415 with caution. Plot 3,4,6 and 7 only show points that have an error estimate of less than 1 mm. Plot 7 shows a better correction than plot 6, this is not a surprise given the more complex correction used.

Plot 10 shows the difference between a linear fit to, and the measured value of, the z coordinate as a function of plane number. The error bars show the error in the measured position and do not include the small error in the fit.

Survey Lug Data

The survey lug data set is the smallest of the four data sets. The survey lugs are only on every fifth plane. Furthermore, only the z measurement is used as the survey lugs are not always put in the same (xy) point each plane.

Results:

The Survey Lug Data plot is shown in Plot 8. This plot shows the average z position of the 8 lugs as a function of plane number. The average pitch from the fit is 59.46 mm/plane. This is about 0.03 mm/plane larger than the fit obtained from the collar measurement and is the same as the axial bolt measurement. This is different from the measured value of 59.51 mm/plane from SM1.

Ear Data

Results:

The ear data set is for diagnosing warp in the planes. The ear data was only taken for z information as the location of the x-y measured point was never exactly the same. This data was never used for any diagnosis by itself. The ears were always compared to the two closest axial bolts. The east ear was compared to axial bolt 7 and the west ear was compared to axial bolt 8.

Results: Plot 9 shows the ear data set. The data is for the most part consistent with expectation. The only exception being a few points where there is a large (unphysical) variation due to a failure in the system or user error. The lines are drawn to aid the eye.

Comparison between SM1 and SM2

Measurement	SM1 (NuMI-NOTE-GEN-866)	SM2 (this document)
Axial Bolt	59.49 mm/plane	59.46 mm/plane
Collar-Z	59.49 mm/plane	59.43 mm/plane
Survey Lug	59.51 mm/plane	59.46 mm/plane

Comparison of Pitch from the same three measurements in SM1 and SM2.

Comparison of SM1-SM2 gap from different fits

Fit Used	SM1	SM2	Difference
Axial Bolt	6.2 cm	116.4 cm	110.2 cm
Collar	7.4 cm	118.4 cm	111.0 cm
Survey Lug	1.6 cm	112.3 cm	110.7 cm

This comparison is made by subtracting the constant term in the linear fit for SM1 and SM2 for the three different fits. The simple average of these three is 110.6 cm which is very close to the measured value of the gap (110.8 cm).

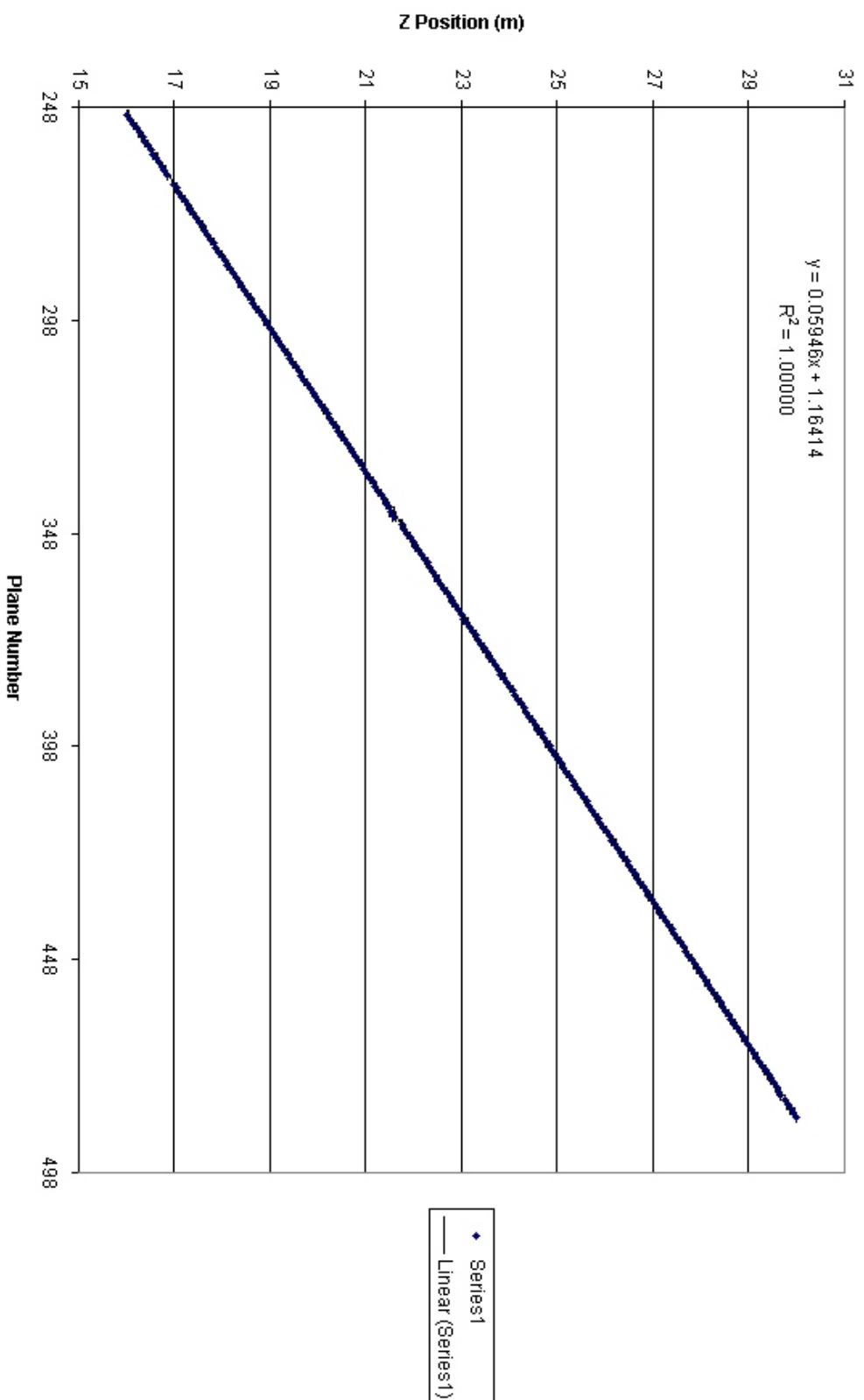
Conclusions

The survey data for SM2 was useful for the construction of the detector. A comparison between SM1 and SM2 show that the detectors are very similar. The pitch of the detectors agree to ~ 0.05 mm/plane. The estimated width of the gap agrees to 2 mm to value measured by hand.

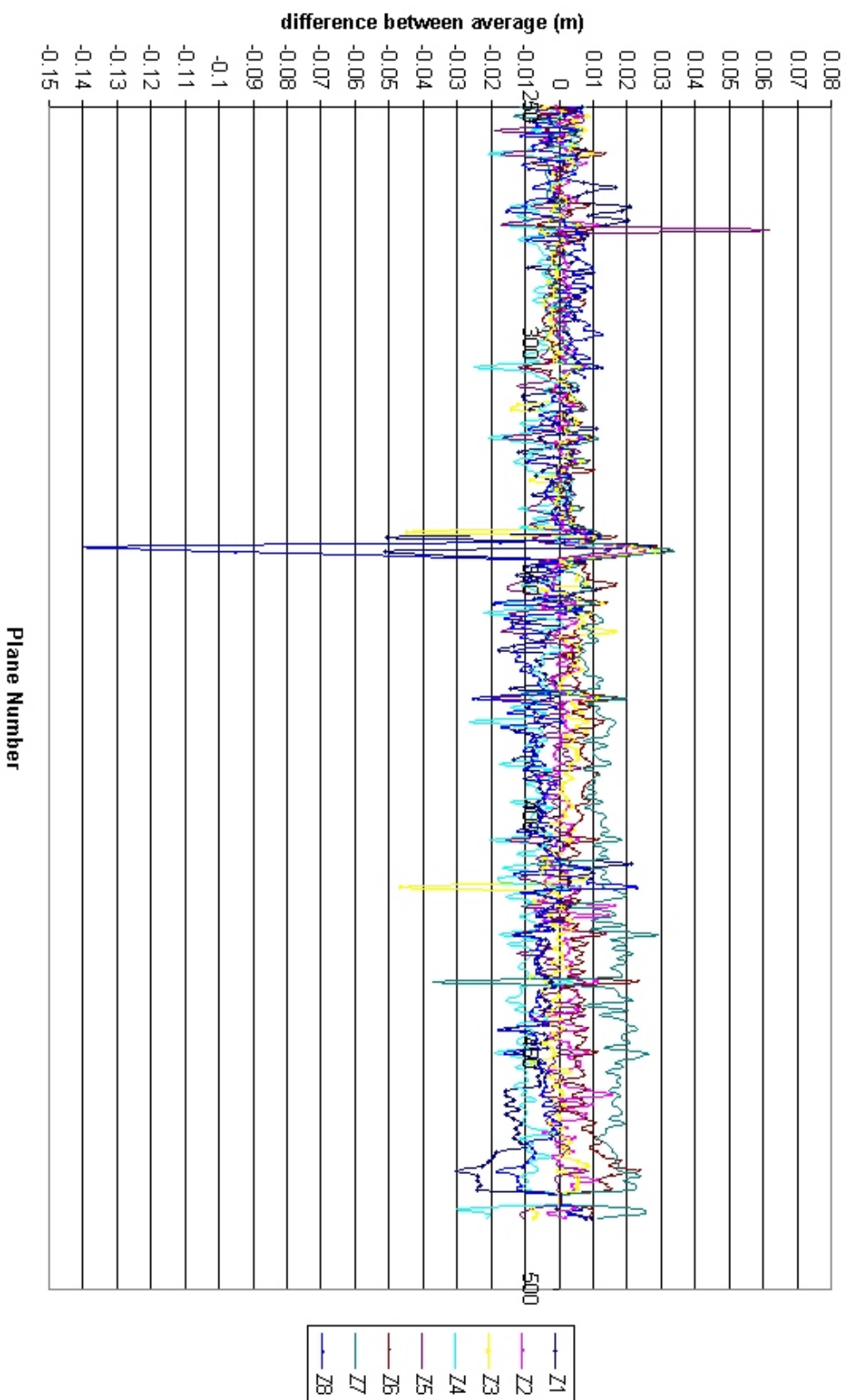
Acknowledgments

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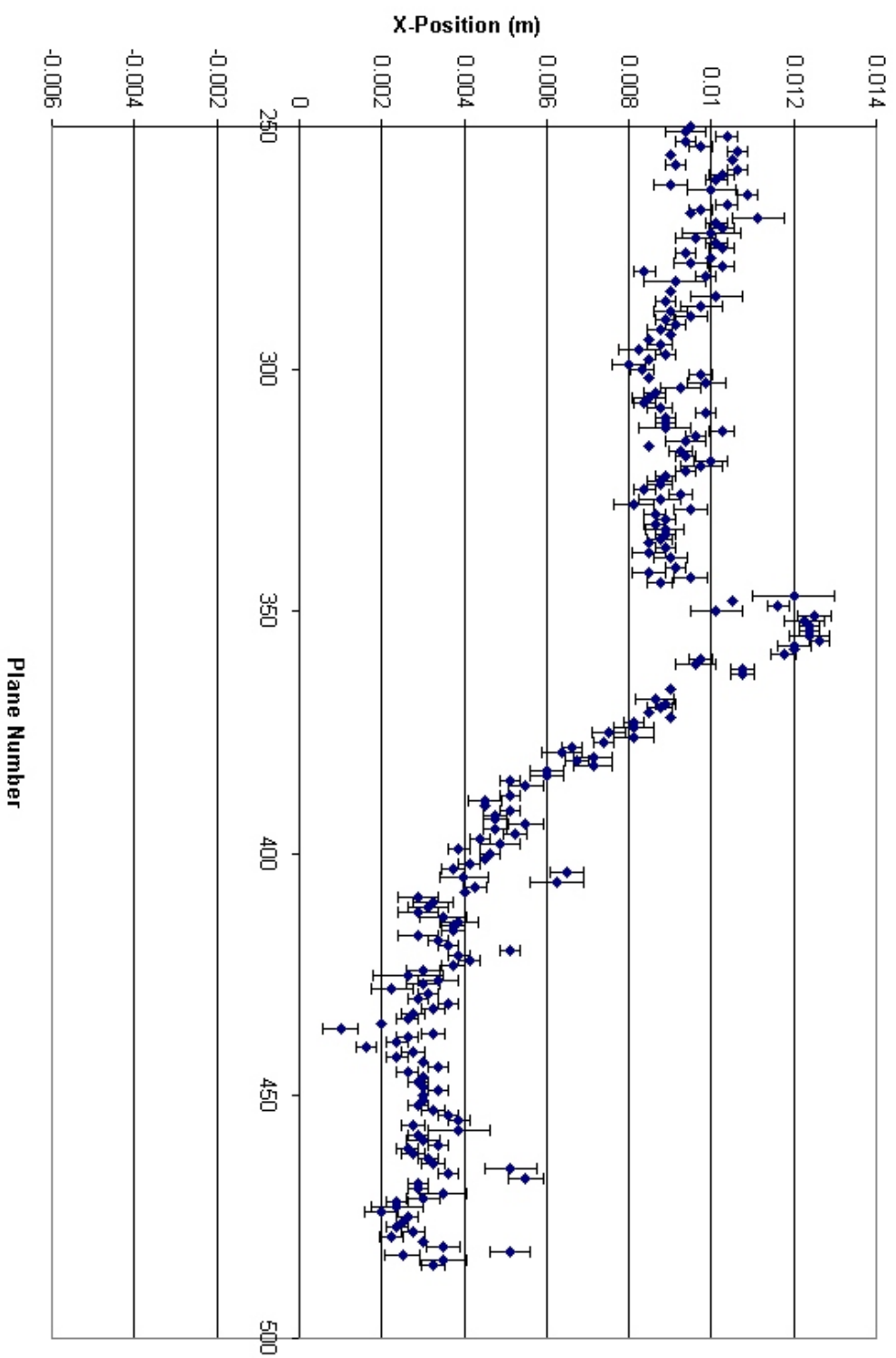
Average Axial Bolt Location in Z Direction (PLOT 1)



Axial Bolt Delta Z (PLOT 2)

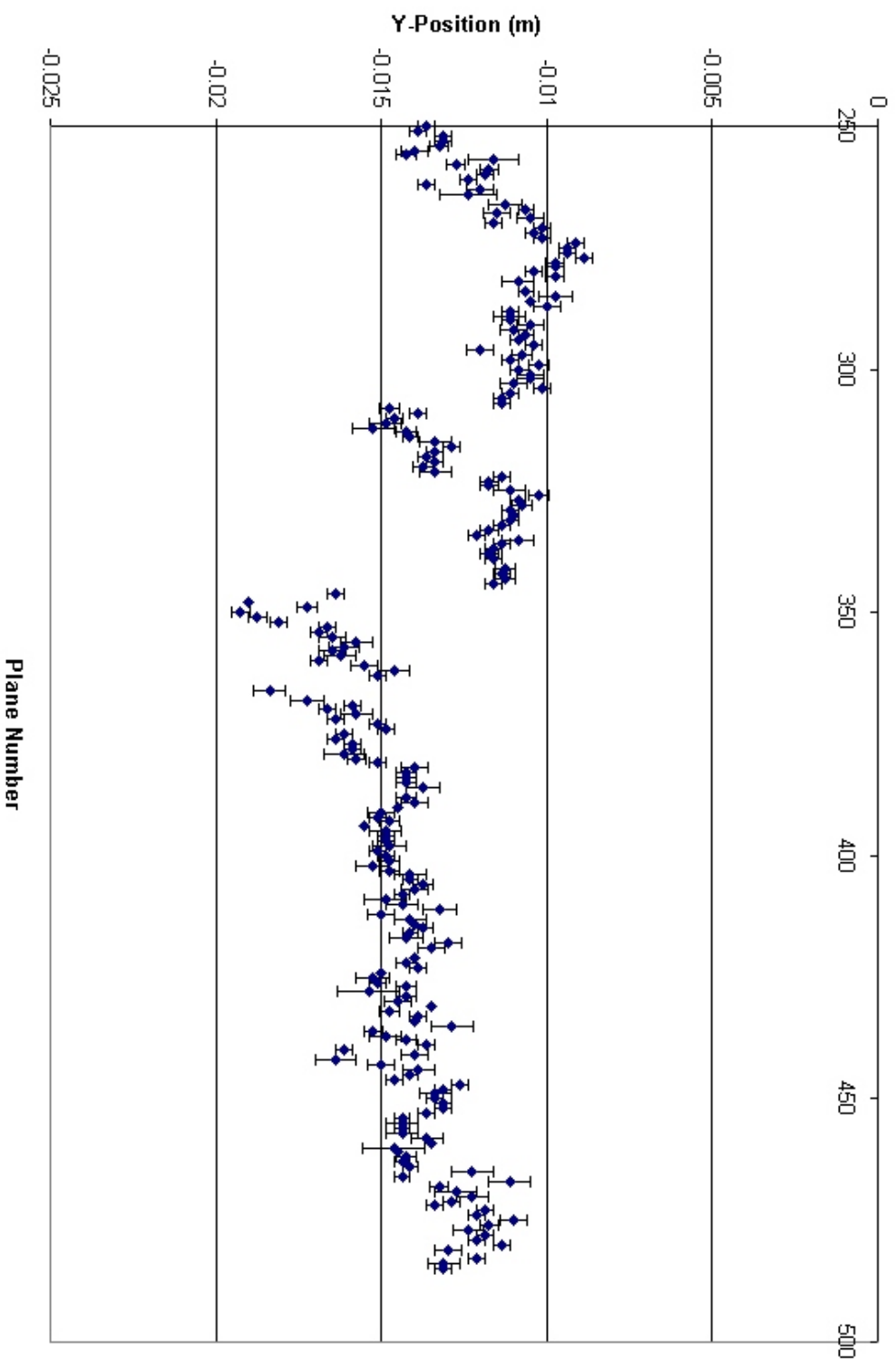


Collar X-Position (m) with point cut < 1 mm (PLOT 3)

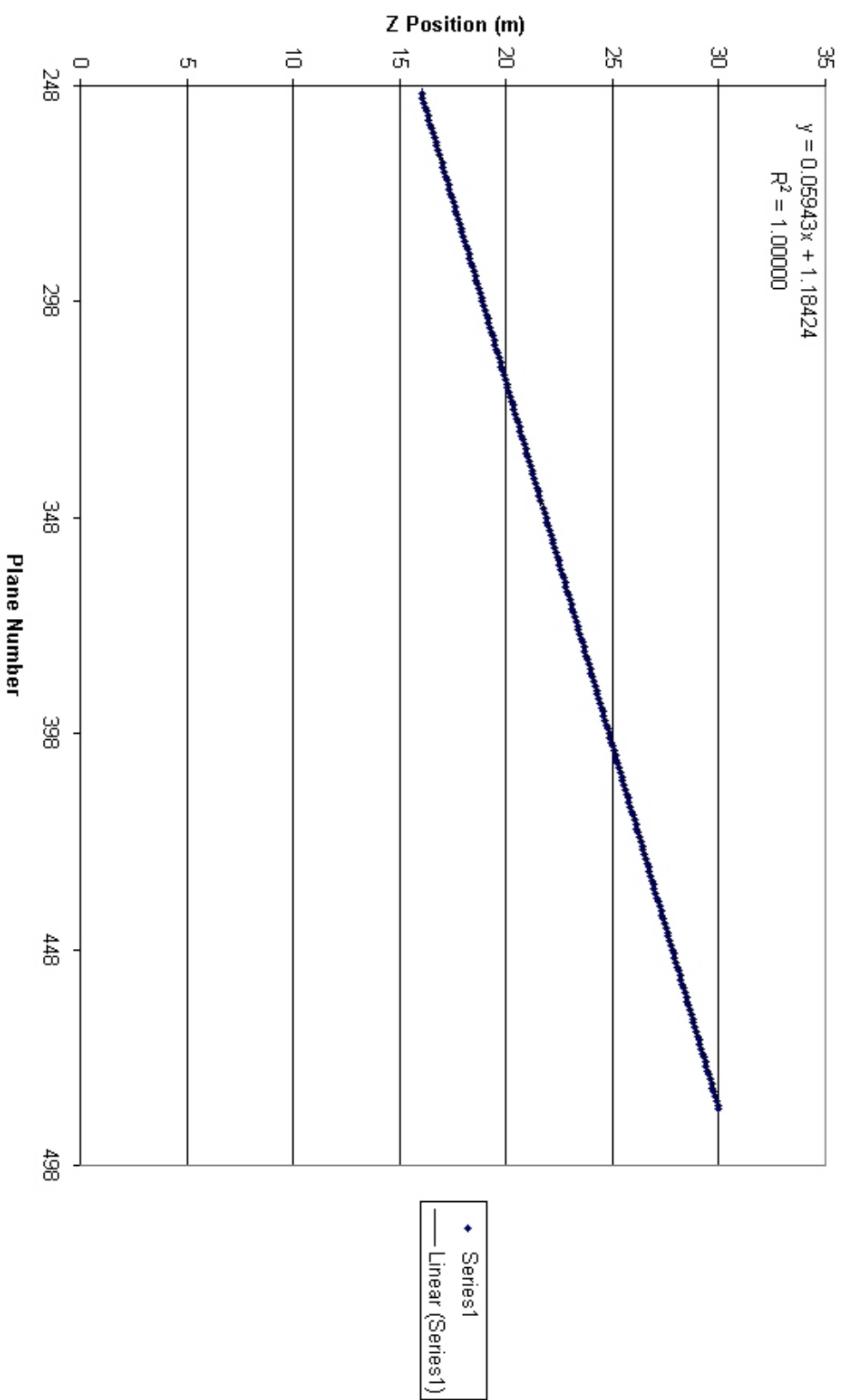


◆ Series1

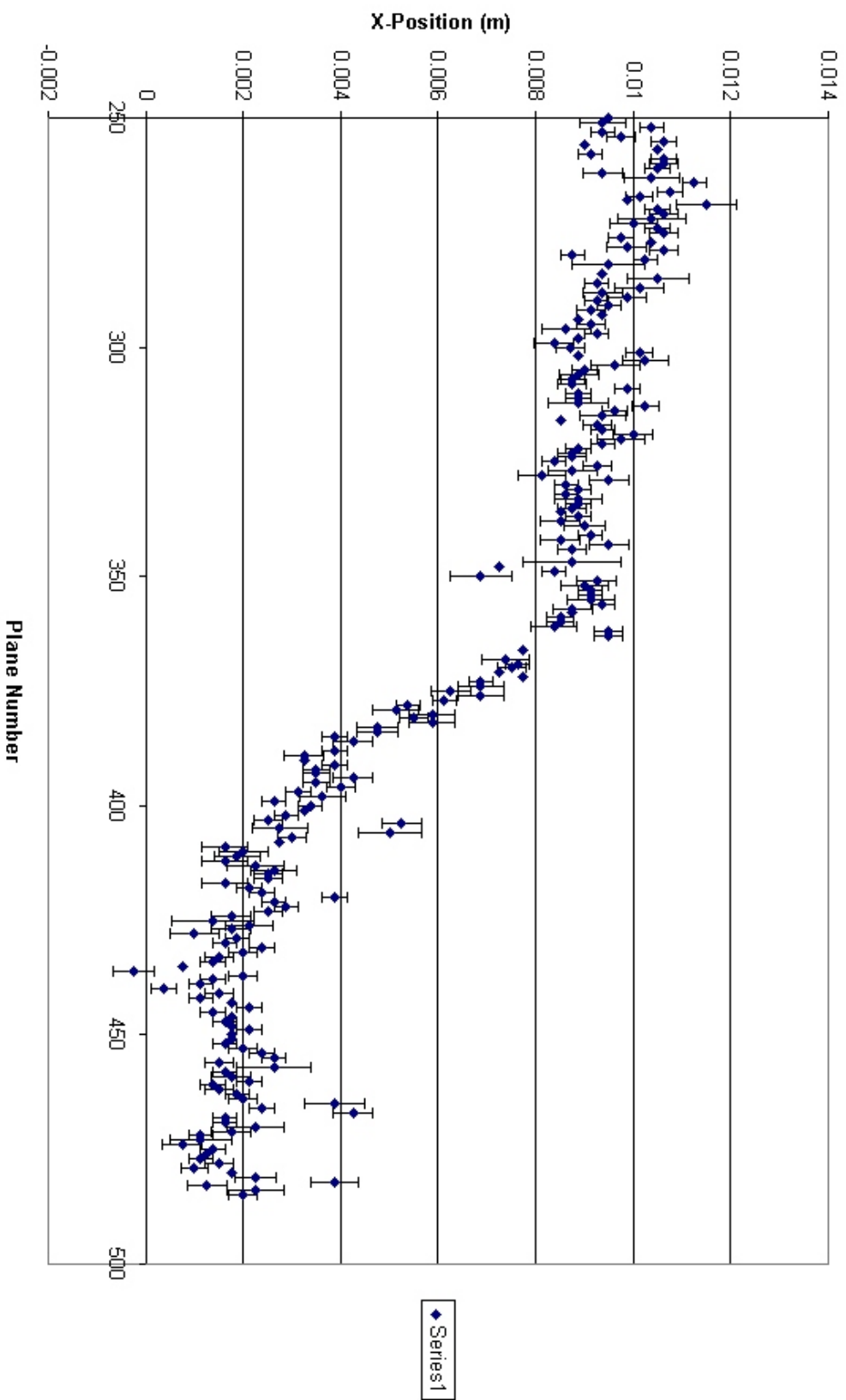
Collar Y-Position (m) with point cut < 1mm (PLOT4)



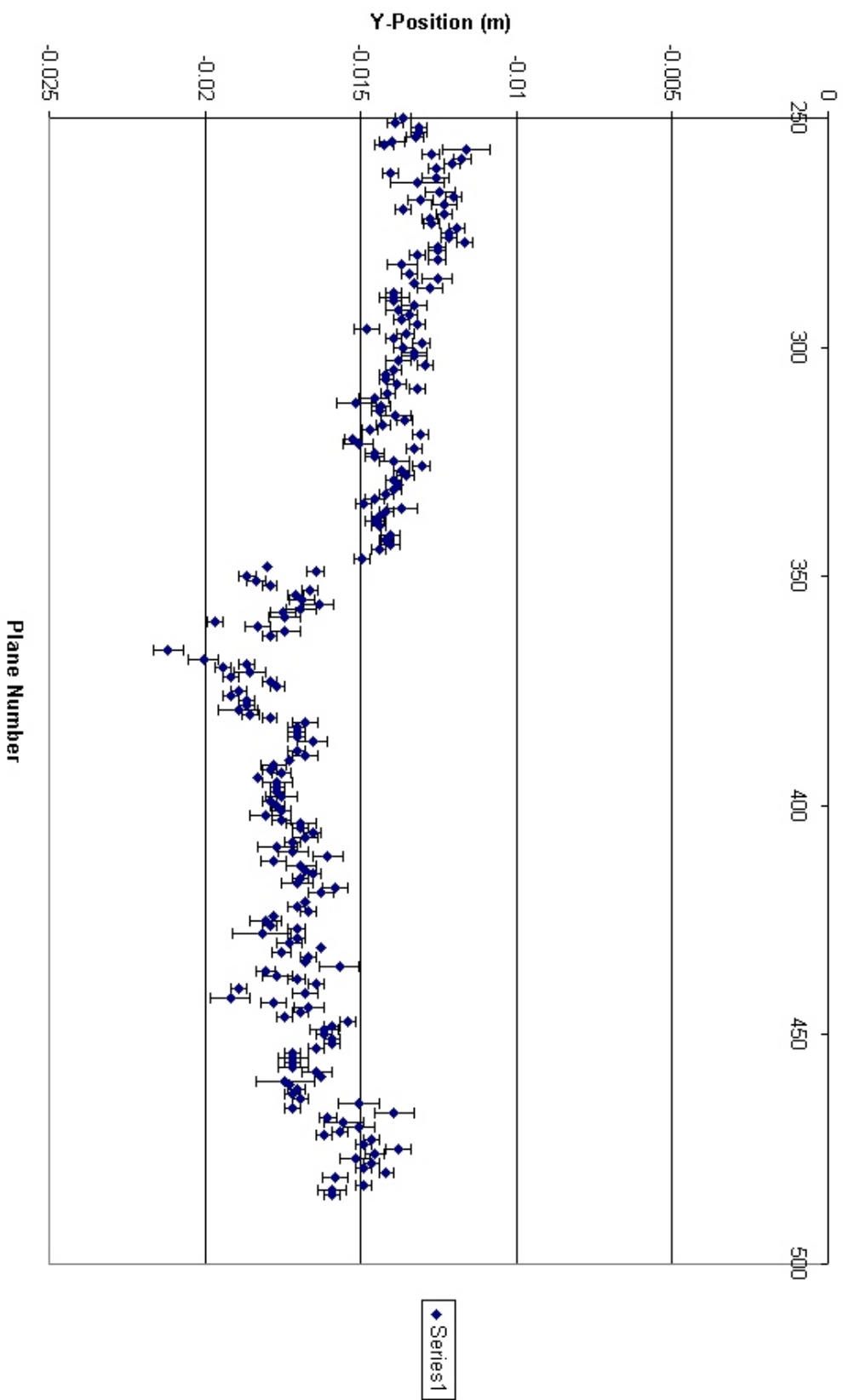
Collar Z-Position (PLOT 5)



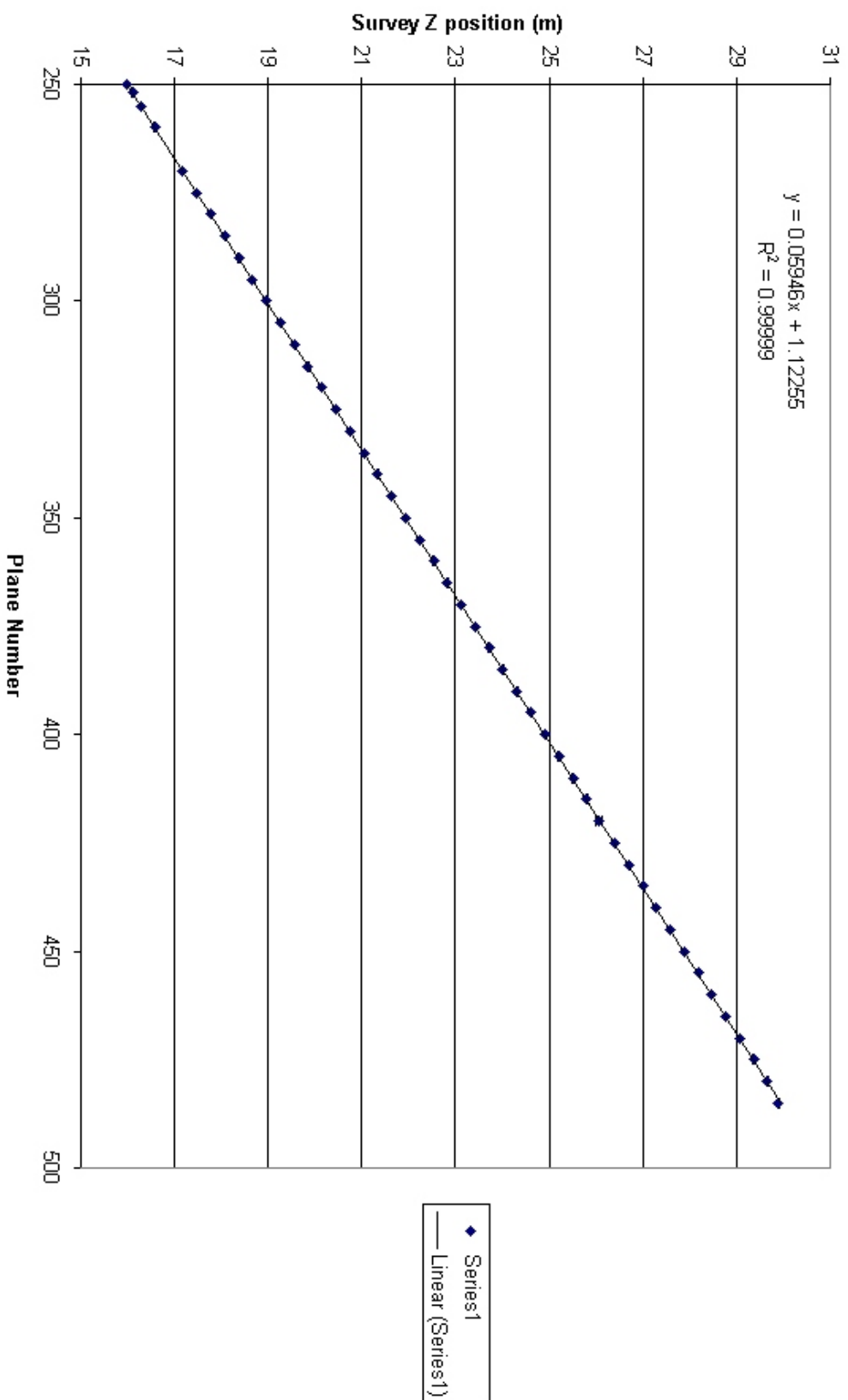
Corrected X-Position with point error < 1 mm cut (PLOT 6)



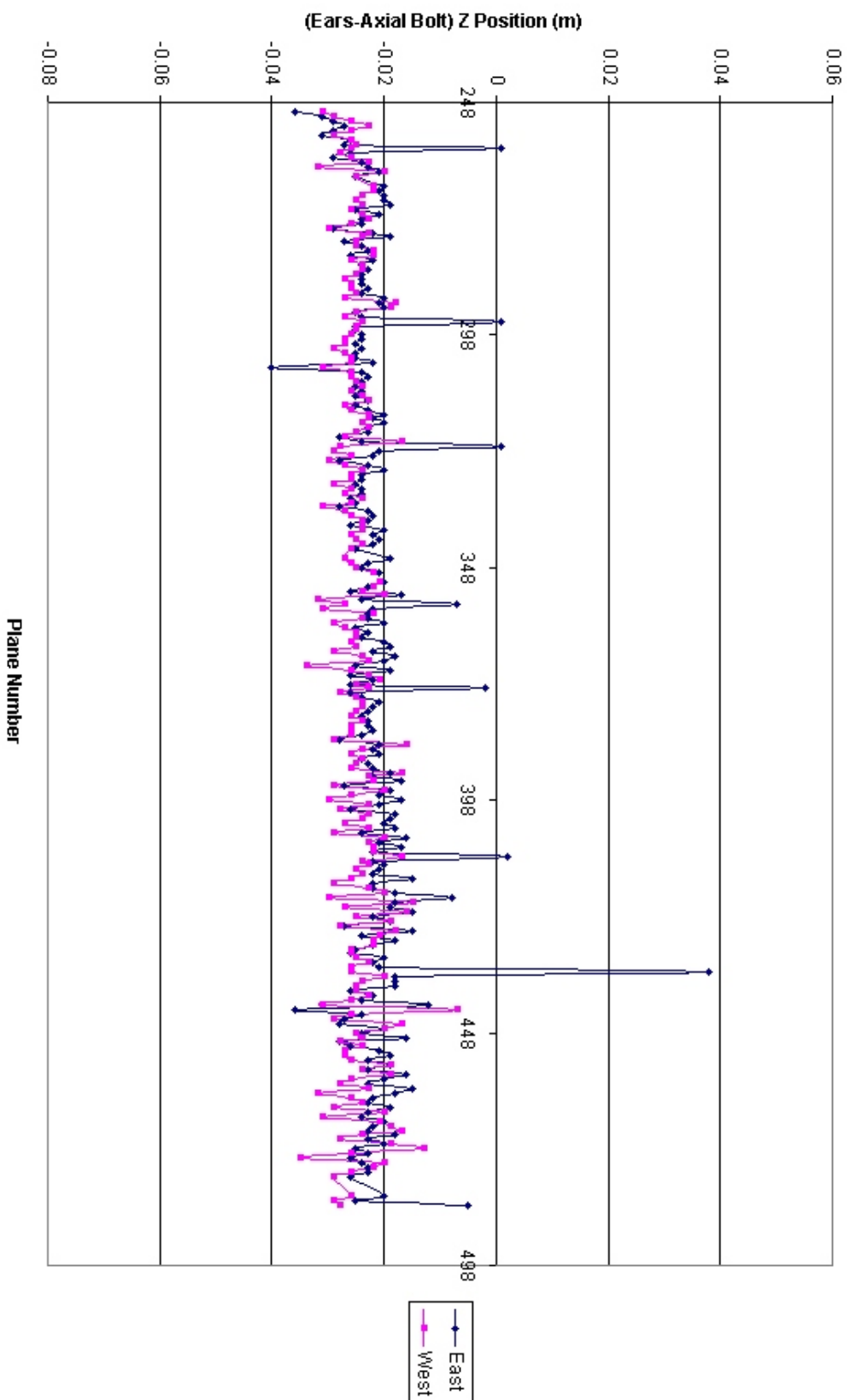
Corrected Y-Position with point error < 1mm (PLOT 7)



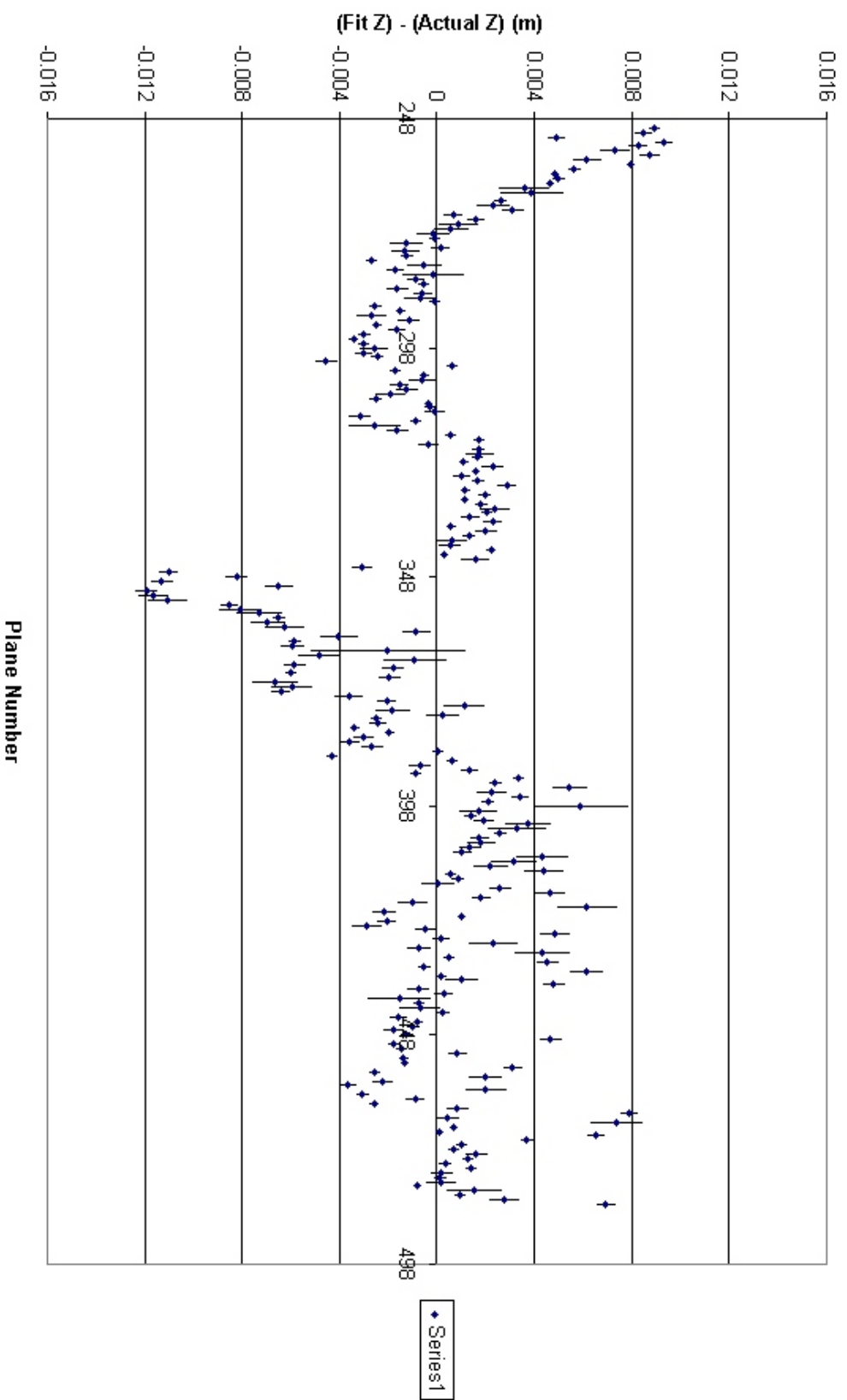
Survey-Z (PLOT 8)



Ears Plot (PLOT 9)



Delta-Collar-Z (PLOT 10)



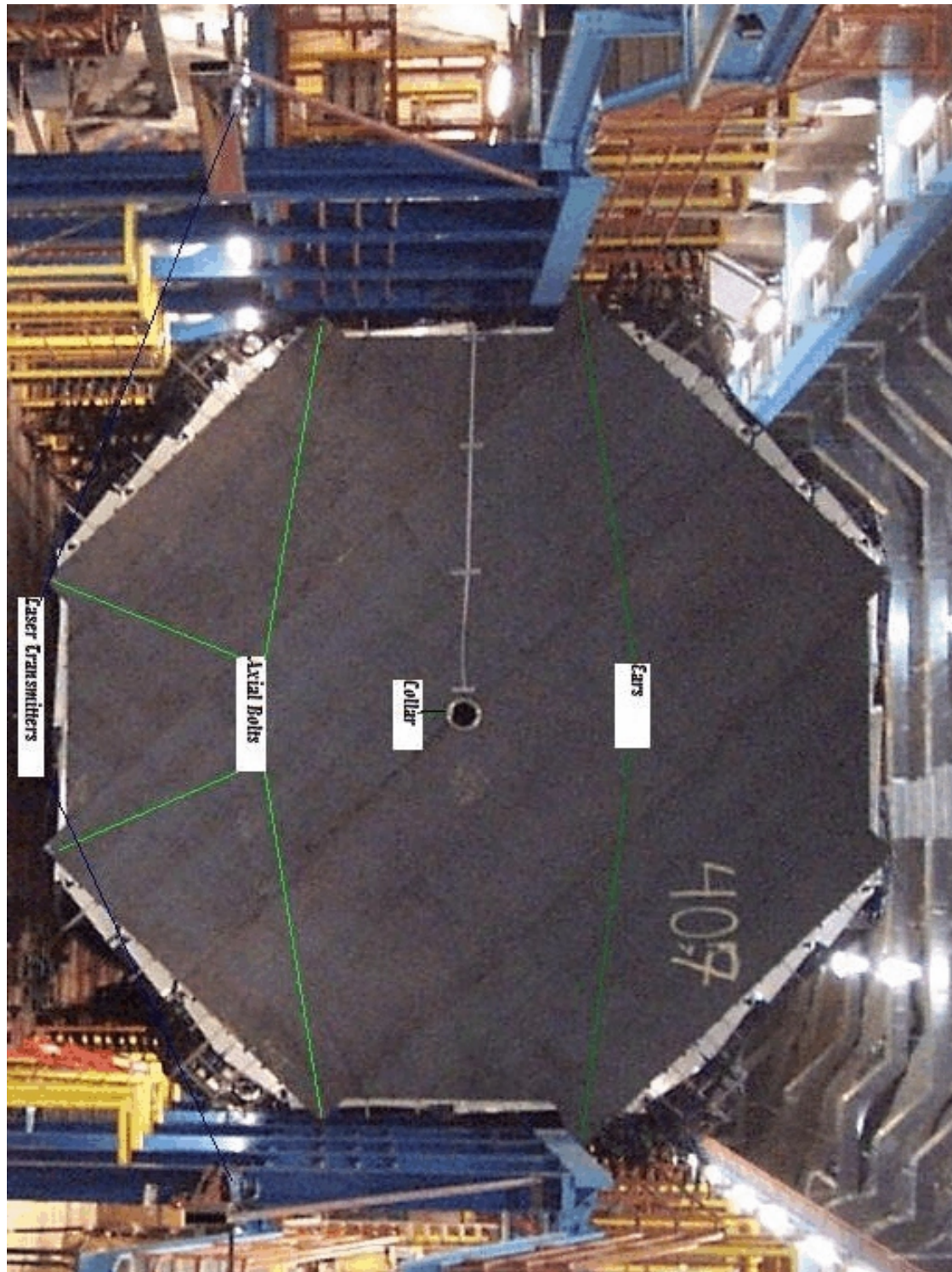


IMAGE 1:Image based off photo by Jerry Meier. This shows the location of the collar, four of the eight axial bolts, the two ears and the two laser transmitters. Note: For most of the construction the two laser transmitters were placed on the columns, only towards the end was this not possible.